Figure 6.26 – Cyclinderical filter air purifier

6.5 INSTALLATION

6.5.1 HUMAN FACTORS

The recommendation to install filters vertically, with horizontal airflow, is discussed in Chapter 4. When practicable, single-filter installations should be located where they can be reached for service and testing without workers having to climb ladders or scaffolding. This requires a consideration of human engineering factors, i.e., the reaching and lifting capability of the average man. The reaching and lifting dimensions of female workers are substantially smaller.[7] Analysis of the recommended weight limits indicates that handling a 1,000-cfm HEPA filter in the body positions often encountered in filter-change operations is at the upper range of personnel capability (higher loadings result in lower man-efficiency) and that handling of adsorber cells is well beyond the limits for one person. Consideration must be given to the positions that a worker must assume to perform the required task. If the worker must hold his hands overhead for any length of time, fatigue may result. If crouching, bending, or squatting is required, the worker will soon become stiff, which will contribute to a loss of efficiency. If a worker has to hold a heavy weight while performing a precision operation (e.g., supporting the weight of a filter or adsorber cell while trying to fit it between duct transitions or into a restricted opening), the stress of the combined task will become fatiguing and a mistake is likely to occur.[7] All of these factors are compounded when the worker must wear protective clothing and respiratory protection. In addition, protective clothing adds to the worker's spatial requirements and limits mobility. For HEPA filter and adsorber cell installations, location of the filter or housing at an elevation between knee and shoulder height is recommended.

6.5.2 FUME HOOD FILTER INSTALLATIONS

The wide, often unpredictable variety of chemical operations conducted in laboratory fume hoods makes the selection and installation of HEPA filters difficult and uncertain. Corrosive fumes may damage the filter and its mounting, and moisture and heat from hood operations may accelerate the damage. Operations that produce steam or moisture should be restricted to minimize condensation in, or the carry-over of water and/or chemical droplets to, the filter core.

Some facilities install the fume hood filters in the attic, usually directly above the hood served. Where such a design is employed, the attic space should be designed as a contamination zone for easy cleanup in the event of a spill, and should not be used for extraneous purposes such as storage and experimental work when radioactive materials are handled in the hood.

Hoods in which perchloric acid and certain other chemicals are handled should be provided with wash-down facilities to permit periodic decontamination of the hood and ductwork (perchloric acid hoods should not be used for handling other materials because of the explosion hazard). Off-gas scrubbers are often provided in hoods. Both wash-down facilities and scrubbers generate substantial quantities of sensible water droplets. Provision of demisters that meet the requirements given in Section 3.6 should be considered to protect the filters and their mountings. Moisture collected in the demister should be conducted to a hood drain rather than permitted to fall back into the workspace of the hood. Demisters should have adequate handling space and be easily accessible for cleaning, inspection, and replacement. Where incandescent particles or flaming trash can be released to the hood exhaust stream, a spark arrestor may be needed to protect the HEPA filter. This arrestor can be either a commercial flame arrestor, a metal-mesh graded-density demister, or as a minimum, a piece of 40-mesh metal cloth. In any event, the arrestor must be located at least 1 to 2 ft ahead of the HEPA filter and must have easy access for cleaning, inspection, and replacement.

Heat sources such as heating mantles, furnaces, and Bunsen burners are common equipment in laboratory fume hoods and should be planned for in the initial hood and exhaust system design. Extended lengths of duct between the hood and filter can provide substantial cooling; but to be really effective, a length of at least 100 ft is needed. Such a length is often impractical, and control of heat-producing operations by limiting the size of heat sources, insulation of furnaces, etc., or use of air cooling methods such as sprays, must be relied upon. Chapter 10 discusses operational control for fire prevention and heat control in HEPA filter systems.

6.5.3 Portable Air Cleaning Units

The use of portable HEPA filtration systems has become quite prevalent within the nuclear industry. Radiation protection standards stress the use of engineered controls, principal localized ventilation, and containments as the primary means of controlling occupational exposure to airborne contaminates. Decontamination and decommissioning activities utilize supplemental ventilation to control the large amounts of dust generated by demolition activities, especially as existing facility ventilation systems are decommissioned. Portable air filtration systems pose their own unique challenges to both the designer and the end user. As with commercial side-access housing, well-designed portable filtration systems as shown in **FIGURE 6.27** are much more than "black boxes." Careful evaluation of system requirements, selection and integration of components, and attention to construction methods are all required to ensure a functional, effective, user-friendly system. These same considerations should also apply when evaluating the many commercially available portable air-cleaning units for use. This process has been made somewhat difficult, however, due to a lack of industry standards that specifically address portable HEPA filtration units.

Figure 6.27 – Portable filter unit

Most procurement specifications for portable HEPA filtration systems are developed by distilling the consciences standards developed by ASME—typically the pertinent sections of ASME N509[9] and N510[10] and the more recent, superceding ASME AG-1.[4] These standards address the in-place, safety-significant ventilation systems for nuclear facilities. While many aspects of these standards are applicable to portable systems, wholesale application without consideration of the unique features and functionality of portable systems may result in unrealistic specifications that are difficult, costly, or impossible to meet. Compromises need to be made, but without sacrificing the overall functionality and safety of the equipment. The balance of this section is devoted to discussing the features and functional requirements that should be considered when selecting or specifying portable HEPA ventilation units for use in environments where nuclear or other hazardous contaminant are present.

6.5.3.1 Operational Considerations

Like any other ventilation system, a portable HEPA filtration system must be designed to move the appropriate amount of air, effectively clean that air, and maintain adequate environmental conditions within the workspace. Unlike permanently installed facility systems, however, the ultimate applications of the portable systems are rarely known. They may be used for ventilating confined spaces, providing general area air exchanging, or providing high, localized, capture velocity in support of cutting, burning, grinding, or other mechanical and maintenance processes. Unless the system is intended for "one time, one application" use, it must be designed and constructed with great flexibility to perform well under a variety of operating conditions. In many cases this results in a system that is overkill for some applications, but marginal for others. Some thought must be given to the expected use of the equipment, and some basic operational questions should be asked to better define the required features. Examples include:

- Is particulate the only contaminate of concern, or will gas adsorption also be required?
- Is the expected operating environment or contaminant corrosive or does it contain other contaminants that might affect the materials of construction?
- Will the unit be used indoors or outdoors?
- What will be the ambient and process air temperature extremes?
- Will the unit be used in areas where there is high relative humidity or entrained water?
- Will the unit be used in areas where potentially explosive concentrations of gases or dust will be present, requiring special hazard class electrical components?
- Does the process or contaminant warrant redundant (series) HEPA filtration for added protection?
- Will the unit be subjected to high system losses due to using long lengths of temporary, flexible ducting and/or multiple filtration stages?
- Is heavy dirt loading expected that may require larger, more robust prefiltration capacity?
- Does the relative hazard of the contaminant require the added protection of bag-in/bag-out filter changing?
- What power is available to run the equipment? [Low voltage and amperage and single-phase power supplies can severely limit the capacity of the ventilation system.]
- How much space is available to stage the equipment? Is a single, larger unit supporting multiple exhaust points more workable, or are small units placed local to the work more appropriate?
- What is the duration of the project or operation that will be supported by the portable system? Is the unit intended to be reused for many times over years, or is it a one time application? [Durability and ruggedness of construction can be greatly impacted.]

Careful consideration to these types of questions will better define to which compromises must be made to design a usable system.

6.5.3.2 COMPONENT CONSIDERATIONS

Fan Assemblies

The motor blower forms the heart of the system. Typically, centrifugal pressure blowers are used on portable systems. These relatively compact fans are available in a wide range of performance and materials of construction. Cast aluminum housing and wheels are common, as well as fabricated steel. Fiberglass, PVC, and other nonmetallic blowers are available for processing air with corrosive contaminants. Regardless of the type of fan used, the blower performance should be matched with the intended application. A fan with high static capabilities at the required flow rate is needed for a portable system that will be expected to operate with high system losses such as large amounts of flexible ducting on the inlet or discharge or when high filter loading is expected. Likewise, if the unit is only intended to provide local recirculation without high system losses, a fan with lower static pressure capabilities is acceptable. Blower performance should be developed using ANSI/ASHRAE Standard 51[11] and AMCA Standard 210.[14]

Motors used in conjunction with the fan are typically direct drive systems. Belt drives are acceptable, but tend to be larger (less portable) and require more preventive maintenance. Belt-driven systems have the added advantage of adjustable fan speed (by sheave selection) to better tailor system performance. Due to advances in motor and solid state controller design, speed control by variable frequency drive has become popular and cost-effective for three-phase motors. Motors should be specified as totally enclosed fan-cooled to protect them from internal contamination. If frequent wash-down with high-pressure water is expected, wash-down duty motors should be specified. Likewise, motors with appropriate hazard class ratings should be used in hazardous locations in accordance with the National Electrical Code (NFPA70) [12].

Electrical starters should be mounted on the unit. National Electrical Manufacturers Association (NEMA) 12 enclosures should be used to minimize internal contamination, and NEMA 4/4x enclosures and liquid tight conduit should be specified for units intended for outdoor application or where direct water wash of the unit is expected. Reference NEMA Publication 250[17] for electrical enclosure testing requirements. Alternate enclosure testing standards such as IEC (reference IEC publication 529[18]) are equally acceptable. The important point is that the electrical enclosures and wiring should be suitable for the intended operating environment, including any special NEC hazard class requirements. Overload protection is suggested for all electrical starters. Special attention needs to be paid to using three-phase motors and starters. Due to differences in wiring methods between the power supply and the portable systems, starter fan rotation can be easily reversed with three-phase motors.

Fan and motor assemblies should not be rigidly mounted to the system's cart or the filter housing/transitions. Vibration isolation should be used for the motor, and a flexible boot or other vibration-isolating connection is needed between the filter bank and the blower. Vibration isolation will reduce noise significantly. Blowers should always be mounted on the downstream side of the filters, thus ensuring that the filters and ductwork are at a negative pressure with respect to the environment. All motor blower assemblies must have appropriate safety guards over the blower inlet and outlet (if normally accessible), as well as shaft, pulley, and belts, if used.

Filters and Filter Housings

Any single, standard-sized, HEPA filter can be readily incorporated into a portable filtration system rated 1,500 cfm or less. HEPA filters should meet the requirements provided in Section 3.2. Since the size of the portable system is quite important, small, non-standard-sized HEPA filters are more appropriate for low-volume ventilators. The same basic construction requirements described in Section 3.2 should be used for these filters as well. Gasketed and gel seal filters can both be used in portable systems, provided the clamping/holding mechanism stays engaged as the unit is moved.

One unavoidable consequence of the compromises made when constructing a portable air cleaning system is that the blower performance and filter ratings may not always match. A portable system designed to support a long length of ductwork and other system losses will move considerable more air when it is operated with lower system losses. Depending on the filters used, the fan may move air at a rate considerably higher than the filter's rated capacity. Excessive overdriving of HEPA filters should be avoided. Some overdriving is acceptable and should generally not exceed 1.3 to 1.5 times the rated filter capacity at 1-in. differential pressure. Overdriving beyond this range can lead to excessive differential pressures on the HEPA filter. The blower's fan curve will indicate the system's maximum potential flow rate. The free airflow rate, or the flow at zero in.wg static pressure, is the maximum possible flow that the fan can develop. Since the blower is connected to a filter bank, some system losses are present, so the free air rate is not a good indication of maximum flow. The flow rate at approximately 1 to 1.5 in.wc is a better indication of the maximum flow that the blower/filter system can be expected to deliver.

The filter housing can be nothing more than typical side-access housing. Housing with bag-in/bag-out features provides added protection from high-risk contaminants or for units used outside. Depending on the contaminants present, the use of a side-access housing may not be warranted. Considerable size, weight, and cost can be saved with alternate filter-retaining methods. Filter sealing/housing arrangements or traditional side-access housing have been successfully used for many years. These range from using nipple connect filters coupled to a blower to using conventional 24- by 24- by 11.5-in. filters clamped between an inlet and outlet transitions. **FIGURE 6.28** depict several portable system arrangements. Whichever method is used, the filter frame and clamping method should meet the standards previously discussed in Section 6.4. The sealing surface must be flat, square, fully welded, and ground smooth. The filter sealing surface must be fully welded to the pressure boundary of the filter housing. The clamps or latches retaining the HEPA filter should exert the recommended sealing force (20 psi of gasket area), and use a spring-loaded or tension method to ensure that a positive clamping force is maintained (this is not necessary when gel-sealed filters are used). Since portable systems are designed to be moved, whichever clamping or housing method is used should adequately protect the filters and prevent unclamping or dislodging of the filter due to cart movement. The system's cart should be sufficiently ridged in construction to limit the amount of flexing seen in and by the filter frame and housing. When the filter is exposed, only metal-cased HEPA filters should be used.

Prefiltration should be integral to the portable system. Prefilters should be accessible independent of the HEPA filter and should not require unclamping of the HEPA filter during change-out. Additional in-line prefiltration may be needed for heavy dirt loading applications such as concrete cutting, abrasive blasting, and plasma arc cutting. Moisture separation as well may be required, which can be addressed with demisting pads integral to the portable system or with supplemental dehumidifiers in line.

Adsorber beds can also be configured on portable carts. The carbon cells can be adapted as part of the HEPA system or as a separate stand-alone assembly that is interconnected with the HEPA blower skid on an as-needed basis. Virgin-grade carbon beds, available in both V-bed and Type II tray design or in large radial flow configurations, can also be incorporated to address other gaseous contaminants such as volatile organics.

Figure 6.28 – Typical portable systems

6.5.3.3 CONSTRUCTION

Portable equipment used in an industrial setting is subject to abuse. As such, the construction of a portable filtration system needs to be rugged and suitable to a harsh industrial environment. Transitions and housing pressure boundaries should be fully welded. Abrupt transitions and plenums should allow a minimum of 3 in. of space for airflow expansion. Gasketed and bolted connections, especially on transition to and from the filter, should be avoided because they are prone to loosening and gasket decomposition over time. Assembly should allow access for decontamination purposes. Materials of construction should be compatible with the operating environment. Stainless steel is highly recommended, especially for those components that come directly in contact with the contaminated air stream. Carbon steel can be utilized on the carts and support frames, provided it is suitably coated to prevent corrosion.

Quality wheels and casters should be used on the equipment. At least one set should have a brake or some other means of securing the cart in place. Wheels should be compatible with the surface where the equipment will be used. Hard wheels are suitable for indoor use and are more readily decontaminated, while large pneumatic wheels may be more appropriate for outdoor applications. Wheel design should allow replacement if the wheel becomes contaminated or damaged. On large units, channels for fork truck lifting or lifting eyes will facilitate handling. Lifting points should be conspicuously marked. A stout push handle is a desirable feature. Toe bars can be used for larger skids, allowing the cart to be pulled like a trailer.

Flow control dampers should be incorporated into the unit, especially on systems with multiple connection points. Dampers located in the ductwork closer to the work area may be advantageous if frequent flow adjustments are necessary. Dampers should include a positive lock to ensure that the damper will not move once the desired flow balance is achieved. Blast gates, quadrant control, and butterfly styles are all suitable for flow control dampers on portable systems. If possible, dampers should be installed so that they fail open, thus preventing a sudden loss of flow in the event of damper failure.

Transitions into and out of the filter housing should be tapered to allow better filter utilization and to lower system losses. Tapered transitions unfortunately add considerable length to a portable system, so as a compromise abrupt transitions are frequently used on portable systems where size is a concern. If abrupt transitions (e.g., no taper) are used, a plenum space of at least 3 in. should be left in front of and behind the HEPA filter. This space will allow for airflow expansion, thereby reducing air velocity prior to entering the filter.

Duct connection points should be undersized to allow of connection of flexible ducting. Allow 1/8 in. less than the nominal size of the flex ducting used. For example, a 7 7/8-in. outside diameter connection would be required if 8-in. diameter flex ducting were used. A roll bead, round bar, or other protrusion fabricated into the duct connection point will help secure the duct when a hose clamp is installed behind it. **FIGURE 6.29** shows a typical duct connection with a flow control damper and roll bead.

Differential pressure (DP) gauges should be installed to monitor dirt loading on the HEPA and prefilter. Individual gauges for both stages of filtration are desirable, but a single gauge that monitors both the HEPA and the prefilter is also acceptable. Since the flow rate through a portable system can change significantly depending the routing of ductwork and the adjustment of dampers, the user must be aware that observed changes on the DP gauge may not be necessarily due to dirt only, but may instead reflect a change in the air velocity through the filter element. For this reason it is necessary to ensure that, when assessing dirt loading on the filters over time, DP readings are taken under the same flow conditions. Alarms that indicate high filter DP, as well of loss of airflow, which can be indicated by a very low filter DP, are also good features. The same general caution about the affect of air velocity on filter DP would apply to these alarms as well.

6.5.3.4 SYSTEM TESTING

Portable air cleaning units require the same periodic inspection and in-place leak testing as permanently installed systems. The rough handling and shock they can be expected to experience during transport makes careful inspections and functional tests desirable prior to each use. Installation of aerosol test ports on the filter transitions can make the in-place efficiency test much easier to perform.

Figure 6.29 – Duct connection with flow control and roll bead

6.5.3.5 VACUUM CLEANING SYSTEMS

HEPA filtered vacuum cleaners (HEPA-Vacs) and Portable HEPA Filtration Systems (PHFS) are most commonly used to control friable particulate before it becomes airborne. They are also used to control airborne particles and liquids in and around work areas and to locally control loose debris when work operations could potentially spread contamination. When used in the nuclear industry, the HEPA-Vacs are commonly referred to as nuclear or radiological vacuum cleaners.

Description of Radiological Vacuum Cleaners

Radiological vacuum cleaners are generally well-constructed, well-sealed devices with a HEPA filter on the exhaust. They are normally mounted on a cart with a comfortable handle and lockable and steerable wheels for portability and control during use. The power module consists of a blower powered by an electric motor and controlled by an onboard switch. The filter module consists of a positively mounted and sealed HEPA filter, protected by a prefilter. All units should have a positive plenum (tank)-to-vacuum head seal. Vacuums that have latches but provide a loose head-to-tank seal that depends on the vacuum force to provide a positive seal (i.e., many commercially available shop vacuums) should not be used.

Some vacuum cleaners are equipped with controllers that allow the worker to regulate the flow. This works well in providing negative ventilation in small glove bags. Using HEPA filtered vacuum cleaners can significantly improve how contamination is controlled.

An in-line HEPA filter can be installed in the suction hose to collect radioactive material before it reaches the vacuum cleaner. Fittings can be made to connect the vacuum cleaner hose to the HEPA filter. As debris is sucked into the hose, it is deposited on the in-line HEPA filter instead of the HEPA filter inside the vacuum cleaner. Temporary shielding should be installed around the in-line filter before operation, as the filter becomes highly radioactive.

If a large amount of debris will be collected, installation of a waste drum in the suction hose should be considered to ensure the debris collects in a waste drum and not the vacuum cleaner. Commercial systems are available, or one can be made by welding two pipes into a spare drum lid. As each drum is filled, the lid can be swapped to a new drum and a regular lid can be installed on the full drum. Personnel doses are reduced because the debris is collected directly into the waste drum instead of the vacuum cleaner.

Vacuum cleaners should be constructed of a material that is easily decontaminated without damage to components. Units that use silicone-based material to prevent leakage should not be used. All hose connections should provide positive seals and should be constructed of a material that will not be damaged by repeated use or rough handling.

HEPA filters should have a positive seal and pass in-place leak testing. The filter hold-down clamps should provide the required force (20 lb/in.^{2}) to seal the filter and prevent dislodging during rough handling and repeated use. They should be constructed of a material that will not wrap or bend with repeated use.

The HEPA filter replacement method should be simple and should performable in minimum time to reduce exposure and the chance of radioactive contamination. The vacuum cleaners should be designed to ensure HEPA filter integrity under all conditions of use and to prevent unauthorized or accidental access to the inner surfaces of the vacuum. Units should be constructed with no sharp edges or burrs that could injure personnel or damage protective clothing.

HEPA filters used in HEPA-Vacs and PHFS should meet the efficiency and construction requirements for HEPA filters in DOE STD 3025[15] and ASME AG-1.[4] The maximum flow rate of the device should not exceed the flow rate at which the HEPA filter was efficiency tested. The HEPA filters should be certified at the Oak Ridge Filter Test Facility.

Operation

HEPA-Vacs and PHFS are used to clean up radioactive debris and provide negative ventilation in the work area. Improper use of HEPA-Vacs and PHFS may result in generation of airborne radioactivity, loose surface contamination, or high dose rates. HEPA-Vacs or PHFS used for radioactive material should be marked “For Radioactive Service Only.”

A nuclear safety review must be performed and documented prior to use of a HEPA-Vac or PHFS for fissile material.

HEPA-Vacs or PHFS must be appropriate for the type and amount of radioactive material involved. The health physicist is responsible for determining the levels of filtration required on the exhaust. Programmatic organizations are responsible for the following:

- Maintaining control of HEPA-Vacs or PHFS.
- Ensuring that HEPA-Vacs or PHFS are tested annually. HEPA-Vacs or PHFS must be retested if the integrity of the filter media or the sealing surface of the HEPA filter is compromised, if the HEPA filter is exposed to water or high levels of water vapor, or if the HEPA filter is transported to another area or site.
- Ensuring that HEPA-Vacs or PHFS are properly labeled, controlled to avoid improper use, and serviced or emptied only by individuals trained to do so, and that the health physicist is contacted before they are opened.

HEPA-Vacs or PHFS used in contaminated areas should be equipped with HEPA-filtered exhausts or with exhausts that are directed to installed systems that are equipped with HEPA filters. Such provisions may not be necessary when these systems are used in areas where only tritium or radioactive noble gases are present or when the material to be vacuumed is wet enough to prevent the generation of airborne radioactive material or removable surface contamination. Extended use of air handling equipment may cause a significant buildup of radioactive material in the ductwork and filters. Periodic sampling of the exhausted air and surveys of the accessible surfaces of the equipment should be performed to assess the radiological impact of equipment operation. While use of the devices discussed above has been proven effective in reducing contamination spread and associated decontamination costs, these benefits must be weighed against the potential costs. Use of engineering controls may require expenditure of worker doses to set up, work in, maintain, and remove the device. There may be financial costs associated with device purchase or manufacture, worker training, possible reduced productivity, and device or component maintenance and disposal.

Testing and Periodic Maintenance

Problems with operating HEPA-Vacs or PHFS are often not visually observable or detectable by onboard instrumentation. Therefore, filter replacement and testing are important to the continued safe operation of the unit. In-place testing is designed not only to validate the HEPA filter, but also to verify the integrity of associated seals, gasketing, ducting, and housings to leakage.

All HEPA filters used in the system should be tested by the DOE Test Facility at Oak Ridge National Laboratory before initial use. In addition, the device should be leak-tested prior to initial use when units have been opened, moved, or transported, as well as annually. Leak tests are conducted by injecting an aerosol challenge into the inlet of the device and measuring the aerosol challenge concentration at the inlet and outlet of the device.

Any entry into a HEPA-Vac or PHFS must be consistent with local radiological controls, and normally would be controlled by a radiological work permit. Radiation and contamination surveys should be performed periodically for HEPA-Vacs or PHFS in use and the labels on these units should be updated. The frequency of radiation surveys should depend on the specific use of the unit.

HEPA-Vacs and PHFS tend to be overlooked when it comes to maintenance and testing. Many standards and procedures address maintenance and testing of permanent HVAC HEPA filtration systems. However, for HEPA-Vacs and PHFS, no national standards and procedures are available. To make matters worse, because of their size and portability, personnel assume that they are functioning correctly. Ironically, these units are capable of discharging contamination over large areas of the work site if filter bypass leakage is occurring.

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their size and portability, personnel assume that they are functioning correctly. Ironically, these units are capable of discharging contamination over large areas of the work site if filter bypass leakage is occurring.

These units by their very nature are prone to leakage. This is mainly because they are small and portable, and thus are transported from workplace to workplace in the back of trucks and are subjected to substantial rough handling by workers. This action creates leaks in units that were previously tested, giving personnel a false sense of security. For this reason, these units should be tested anytime they are moved or transported. When testing these HEPA-Vacs and PHFS, test personnel should apply the same rigorous procedures outlined in ASME N-51[19] and ASME AG-1[4] for the permanent HVAC HEPA filtration systems. After all, HEPA-Vacs and PHFS perform the same functions and have essentially the same components as the permanent HVAC systems.

Reasons For Testing HEPA-Vacs or PHFS

- Poor design of the HEPA-Vacs or PHFS
- Poor workmanship and inadequate Quality Control by the HEPA-Vacs or PHFS manufacturer
- Leaks in the filter media itself
- Leaks due to failure of the adhesive bond between the filter media and its frame
- Leaks between the filter frame and cabinet sealing frame seals
- Leaks between the cabinet main frame and the cabinet housing
- Leaks in the cabinet or housing due to damage in transit or handling
- Leaks from misalignment or misassembly of the HEPA-Vacs or PHFS and HEPA filter.
- Leaks resulting from incorrect or inadequate maintenance
- Leaks resulting from improper installation and operation of the HEPA-Vacs or PHFS at the work site

[Note: Many of the above items may not be applicable to units constructed and certified to ASME AG-1[4] criteria.]

HEPA Filter Vacuum Cleaner Tests

Numerous suppliers manufacture HEPA-Vacs, and each supplier has several models available. This leads to unique characteristics that must be considered when performing in-place testing. As in the permanent HVAC systems, a thorough visual inspection by trained personnel of the unit to be tested should be performed before conducting the test. This inspection should be done using a checklist tailored to the specific make and model to be tested. These units should also be tested for proper flow and suction capabilities. Generally a 4- to 6-in. diameter duct or flex hose 8 to 10 ft long is used to introduce the challenge aerosol to the input of the HEPA-Vacs under test. An upstream probe can be fitted close to the end of the hose to enable transition to the inlet connector of the unit under test. The output of the aerosol generator should be directed to the other end of this hose. This configuration usually allows adequate aerosol-air mixing of the aerosol challenge.

The greatest challenge to testing HEPA-Vacs is obtaining a representative downstream reading. For most HEPA-Vacs, downstream air is discharged radially in all directions rather than through a duct (as in permanent HVAC systems). To accomplish this, test personnel usually fabricate a collection hood to collect all of the downstream air discharged from the unit under test and connect a duct or hose to the hood. The hose or duct can be fitted with a downstream probe located at least ten diameters downstream of the hood. After the upstream/100 percent point has been established, a downstream reading should be taken with and without the aerosol generator operating. This is done to verify the background reading. Some HEPA-Vacs generate significant amounts of particles due to their design configuration. If a background reading is detected, it should be recorded and deducted from the downstream reading obtained with the aerosol generator operating.

Portable Filtration Systems Testing

There are two basic designs for these systems—those that "pull" air through the HEPA filter and those that "push" air through it. Therefore, some units have the HEPA filter upstream of the motor/blower assembly and others place the HEPA filter downstream of the motor/blower. The advantages and disadvantages of each design concept are summarized in **TABLE 6.2**.

Table 6.2 – Downstream/upstream HEPA filer locations in PHFS

(+) Advantages	**(-) Disadvantages**
Type A DOWNSTREAM HEPA	Type B UPSTREAM HEPA
(+) easier access to HEPA filter for scanning or leak testing	(-) difficult access to HEPA filter for scanning or leak testing
(+) easier to repair leaks in HEPA filter if allowed	(-) difficult to repair leaks in HEPA filter if allowed
(+) may not require mixing chamber to assure uniform mixing of test aerosol	(-) requires mixing chamber to assure uniform mixing of test aerosol
(-) motor/blower may become contaminated	(+) motor/blower should stay uncontaminated unless filter leaks
(-) cabinet interior may become contaminated	(+) cabinet should stay uncontaminated unless filter leaks

Design, materials, specifications, and quality of construction vary widely among PHFS. These variables have a tremendous impact on overall performance and effectiveness. In particular, the cabinet material must remain rigid and undistorted during shipping, handling, and the rigors of daily operation to prevent the contaminated air from bypassing the HEPA filter. The type and gauge of metal fabrication methods, braces, holes, cracks, fasteners, welds, gaskets, and seals must be designed, specified, and assembled with potential leakage, durability in service, and maintenance in mind.

[*Note:* Much of the above may not be applicable to units constructed and certified to ASME AG-1[4] criteria.]

Testing Problems and Special Considerations

Some of the designers and manufacturers of negative pressure filtration units have not put much thought or effort into creating units with "integrity testing" in mind. Not only do they unintentionally design-in leaks, they also often overlook the inclusion of features that allow access to areas that are critical for leakage testing. Access to the downstream face of the HEPA filter for the purpose of scanning is virtually impossible in most units where the blower is downstream of the HEPA filter. A mixing chamber with baffles is necessary at the inlet of this type of unit to provide adequate mixing. Downstream measurements of the exhaust air stream can be subject to error due to channeling—the opposite of mixing. The aerosol from a specific leak may simply remain concentrated in a segment of the exhaust air stream. Therefore, sampling must be done at various points across the face of the exhaust air outlet, in effect a "scanning" of the opening. A single-point sample is usually not representative of what is in the exhaust air stream. The same considerations are included in making air velocity measurements across the exhaust opening or duct in accordance with ANSI/ASTM 41-2.[16] A single-point reading is not representative.

6.6 REFERENCES

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